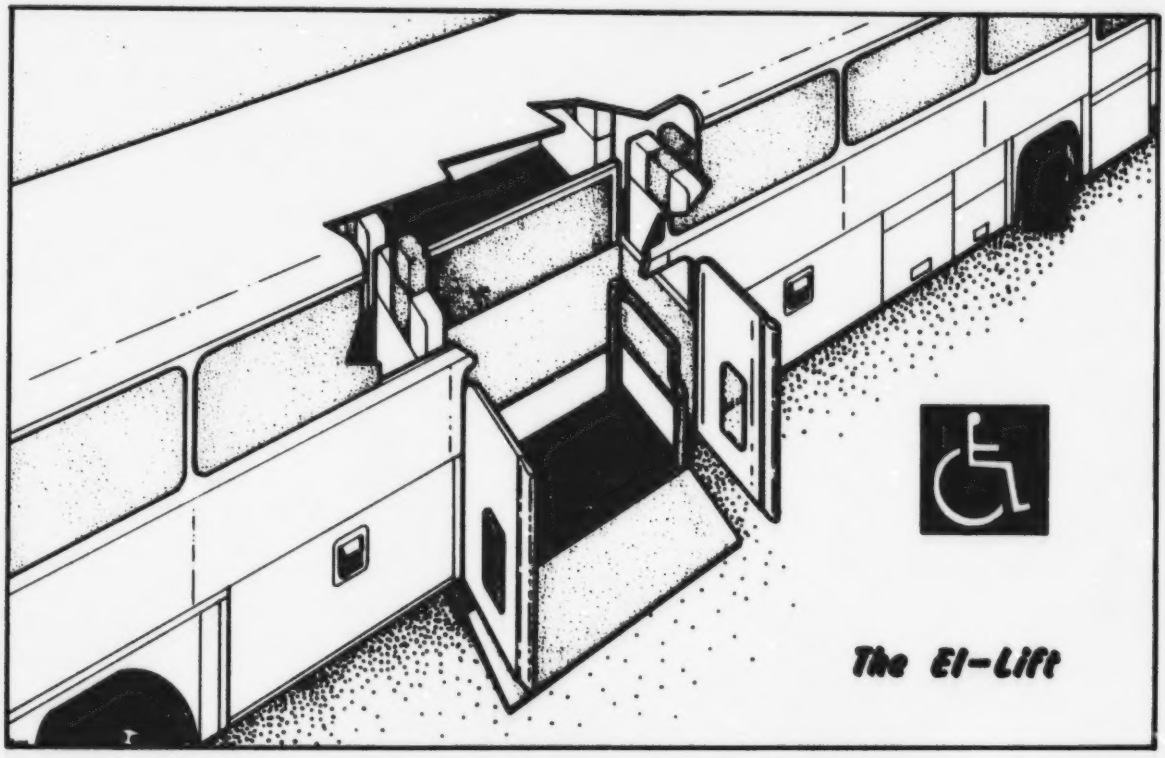
TP 5213 E

Preliminary Engineering Design of an Elevator-Style Access Device (the El-Lift) on an MC-9 Coach



Prepared for
Transport Canada
Transportation Development Centre

By
Lugano Enterprises Ltd.

January 1984

CA1
DTC 845
84
P62
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TP 5213E

PRELIMINARY ENGINEERING DESIGN OF AN ELEVATOR-STYLE ACCESS DEVICE (THE EL-LIFT) ON AN MC-9 COACH

by

LUGANO ENTERPRISES LIMITED
WINNIPEG, MANITOBA

Prepared for

THE TRANSPORTATION DEVELOPMENT CENTRE
TRANSPORT CANADA

January 1984

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FORMULE DE DOCUMENTATION POUR RAPPORT

1. N° du rapport Transports Canada	2. N° de l'étude — CDT	3. N° de catalogue du destinataire
TP 5213E	6113	

4. Titre et sous-titre	5. Date du rapport
PRELIMINARY ENGINEERING DESIGN OF AN ELEVATOR-STYLE ACCESS DEVICE ON AN MC-9 COACH	Janvier 1984
	6. N° du rapport de l'organisme exécutant

7. Auteur(s)	8. N° de dossier Transports Canada
P.W. Wagner, L. Kryski	D 1465-433

9. Nom et adresse de l'organisme exécutant	10. N° de dossier — ASC
Lugano Enterprises Limited 104 - 966 Waverley Street Winnipeg, Manitoba R3T 4M5	01SF.T8200-3-3556
	11. N° de contrat — ASC ou Transports Canada
	OSF83-00054

12. Nom et adresse de l'organisme parrain	13. Genre de rapport et période visée
Centre de développement des transports 1000 o. rue Sherbrooke Suite 2421 Montréal, Québec	Final
	14. Code de l'organisme parrain
	CDT 6113

15. Remarques additionnelles	16. Agent de projet — CDT
	T.N. Smith

17. Résumé

Ce rapport décrit l'avant-projet d'un dispositif d'embarquement appelé EL-Lift installé du côté des soutes à bagages d'un autocar MC-9. Il s'agit d'une plate-forme élévatrice complètement protégée par la carrosserie et dont la fonction est de faciliter l'accès aux personnes âgées ou en fauteuil roulant. Une fois élevée, cette plate-forme devient partie intégrante du plancher, et le passager en fauteuil roulant peut y rester grâce à un dispositif d'immobilisation étudié à cette fin. La manoeuvre de levage est automatique à partir du siège du conducteur, mais celle des portes et de la rampe est manuelle. Les portes s'ouvrent de part et d'autre de la baie et, une fois ouvertes, elles sont verouillées, protégeant à la fois les usagers et les passants. La rampe qui facilite l'accès sert de garde-corps, une fois relevée. La personne en fauteuil roulant prend place à reculons sur la plate-forme abaissée dont la rampe aura été rabattue. Une maquette en vraie grandeur de cette plate-forme a été construite et huit personnes en fauteuil roulant envoyées par l'Association canadienne des paraplégiques l'ont essayée. Elles n'ont rien trouvé à redire sur la facilité d'accès.

L'avant projet a montré la faisabilité du concept envisagé mais, en admettant que l'accès se fasse à partir du sol, il faudra que la hauteur de la baie soit ramenée à 1,470mm afin que l'intégrité structurelle du vénicule ne soit pas compromise.

18. Mots-clés	19. Diffusion
Autocar. Handicapés. Accessibilité. Fauteuil roulant. Plate-forme élévatrice	Le CDT dispose d'un nombre limité d'exemplaires.

20. Classification de sécurité (de ce rapport)	21. Classification de sécurité (de cette page)	22. Nombre de pages	23. Prix
Non classifiée	Non classifiée	61	Aucun

REPORT DOCUMENTATION FORM

1. Transport Canada Report No.	2. TDC Project No.	3. Recipient's Catalogue No.
TP 5213E	6113	

4. Title and Subtitle	5. Report Date
PRELIMINARY ENGINEERING DESIGN OF AN ELEVATOR-STYLE ACCESS DEVICE ON AN MC-9 COACH	January 1984
	6. Performing Organization Report No.

7. Author(s)	8. Transport Canada File No.
P.W. Wagner, L. Kryski	D 1465-433

9. Performing Organization Name and Address	10. DSS File No.
Lugano Enterprises Limited 104 - 966 Waverley Street Winnipeg, Manitoba R3T 4M5	01SF.T8200-3-3556
	11. DSS or Transport Canada Contract No.
	OSF83-00054

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Transportation Development Centre 1000 Sherbrooke Street West Suite 2421 Montreal, Quebec H3A 2R3	Final
	14. Sponsoring Agency Code
	TDC 6113

15. Supplementary Notes	16. TDC Project Officer
	T.N. Smith

17. Abstract

This report describes the preliminary design of an elevating device (EL-Lift) to be installed in the right-hand central luggage area of the MC-9 intercity bus. Designed to facilitate bus access for wheelchair and semi-ambulatory passengers, the EL-Lift is a platform travelling in a vertical direction and totally contained and functioning within the periphery of the bus. When the bus is in motion, the platform forms part of the bus floor on which the wheelchair user is stationed, secured by a restraint device. The lift functions automatically under driver control; the two doors and ramp, however, must be manually operated by the driver. The doors open on either side of the lift and lock at 90° angle to the longitudinal axis of the bus. This provides protection for both users and passers-by. A ramp is folded onto the loading surface and, when retracted, acts as a containment barrier. To board, the user backs the wheelchair onto the lowered platform from the ramp. A full-scale mockup of the proposed lift was built and tested by a panel of eight wheelchair users from the Canadian Paraplegic Association. They experienced no problems boarding the elevator.

From the preliminary design it was determined that the lift concept was possible, but, assuming that boarding is from ground level, the lift entrance height clearance may be restricted to 1470 mm in order to retain structural integrity of the bus.

18. Key Words	19. Distribution Statement
Motor. Coach. Bus. Handicapped. Access Wheelchair. Lift. Ramp.	Copies available from Transportation Development Centre

20. Security Classification (of this report)	21. Security Classification (of this page)	22. No. of Pages	23. Price
Unclassified	Unclassified	61	Nil

TDC/CDT 79-005

ACKNOWLEDGEMENTS

Lugano Enterprises Ltd. wishes to acknowledge the assistance of the following:

Uwe Rutenberg of Les Designers Douglas Ball Inc., Sainte-Anne-De Bellevue, for his assistance in helping us establish the user needs and requirements and lift specifications.

The staff of Motor Coach Industries Ltd. for providing technical information and access to the assembly plant.

John Lane of the Canadian Paraplegic Association, Winnipeg, for the organization of a wheelchair user review panel. The panel participated in evaluating the proposed lift configuration and size. The participants of the panel were:

Don Ament
Marianne Bosen
Lucy Deluca
Bill Heindl
John Lane
George Murphy
Tim Thurston
Arnold Schryvers

Paul Tustin of the Rehabilitation Engineering Department, Health Sciences Centre, Winnipeg for providing technical information on wheelchairs and wheelchair lifts.

Gilbert Boyd, St. George's, Newfoundland, for discussion of user's requirements in Newfoundland.

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1. INTRODUCTION

To provide a practical method of public transportation for wheelchair users in Newfoundland, Transportation Development Centre requested a preliminary design of a wheelchair lift for intercity buses. It was suggested that the EL-LIFT concept be used which was developed by Les Designers Doulglas Ball Inc. This lift would eventually be installed in a Motor Coach Industries MC-9 intercity bus to be used for the CN Roadcruiser Service in Newfoundland.

The preliminary design was approached with the goal of developing a lift that was optimal for the application. Since the lift need not have a dual function of stair entrance and lift, an opportunity was provided for less complex design. This reduced complexity would in turn allow higher reliability, lower cost and better serviceability.

The Lugano Enterprises Ltd. (LEL) team evaluated the EL-LIFT concept and felt it was an advantageous approach. Its most prominent feature is that the lift is totally enclosed within the periphery of the bus except for the entrance door and utilizes simple vertical motion as in a typical elevator. After the lift is lowered, the platform, in the original concept, would slide outwards from the vehicle to allow the user to board the platform. Reversing these motions completes the boarding process.

To achieve further simplicity, the LEL team investigated the possibility of deleting the slide and just drive the platform vertically. A hinged ramp would provide the bridge from ground level to the lowered platform. The user would enter the elevator cavity and then be elevated. To ensure the feasibility of this approach, a full-size mock-up was constructed and later tested with a group of wheelchair users. The users were satisfied that the space was adequate for manual and power wheelchairs. They had no difficulty entering and exiting the elevator cavity. Thus, the EL-LIFT concept was modified, eliminating the slide.

The team then proceeded to analyze the effects of the lift cavity on the bus structure as well as evaluating numerous methods for actuating and guiding the platform. Safety was the highest priority. As a result, a ball bearing screw actuator (ball screw) system, driven by an electric motor was selected. Two screws were chosen to provide symmetrical drive and additional safety. The screws would be mounted adjacent to two tracks. A power track system, as used in fork lift trucks, was selected for guiding the platform and mounted on to the wall structure. This system also minimized infringement of the bus passenger space.

2. USER NEEDS AND REQUIREMENTS

A meeting between Uwe Rutenberg of Les Designers Douglas Ball Inc. and the LEL team took place to establish the basic criteria for user needs and requirements. Also further studies were done by LEL of various reports (1 to 6). As a result, the user needs and requirements were established and are shown in Table 1.

1. Safety
2. Reliability
3. Quiet, timely and smooth operation
4. Simple travel motion at any one time
5. Minimum exposure of user outside bus periphery
6. User made to feel as an ordinary passenger as much as possible
7. Pleasing esthetics
8. Ease of ascending and descending platform
9. User interaction for control not required
10. Call for assistance control
11. Restraint system

Table 1 User Needs and Requirements

Some of the above are obvious and will not be discussed.

The quiet, timely and smooth operation generates confidence in the user towards the equipment and makes the user feel more at ease and encouraged to use the lift.

Minimizing the exposure of the user to the outside elements tends to reduce attention from passerbys and passengers as well as discomfort in unfavourable weather conditions.

Attention-getting events such as flashing lights, audible alarms and unusual motions, such as hoisting the user up outside the periphery of the bus, make the user appear conspicuous. This in turn generates an uneasy feeling in the user, Thus, the user should be made to feel as an ordinary passenger as much as possible by minimizing attention-getting events.

The esthetics of the lift should be pleasing and compatible with the bus to make the user feel more fairly treated and more like the rest of the passengers. If the lift esthetics are overly elegant, the user may feel pampered. On the other hand, if the lift esthetics are below the bus norm, the user may feel slighted.

Ascending and descending the lift platform provides various degrees of difficulty for the user, depending on the user's strength. Because of the great variance of this strength, the ramp slope magnitudes should be minimal.

It has been shown that difficulty occurs in training people to use new equipment. (4) Thus it appears more efficient and convenient to allow a trained driver to operate the lift instead of allowing the user to do so.

3. BUS OWNER REQUIREMENTS

The bus owner must make a profit so as to remain in business. To achieve this, the operation must maximize revenues and minimize expenses. The lift affects this operation by eliminating four passenger seating positions (3 in the situation when a wheelchair user is on board) and 17% of the luggage compartment space. The luggage compartment space is also used for freighting goods for additional revenue. The loss of luggage revenue space is even more pronounced if passenger usage is low.

4. SPECIFICATIONS

The specifications for the EL-LIFT were developed from information in Section 2 and 3, the CSA Standard (3), and other reports (4, 6). Figure 1 shows the relationships between the user needs and requirements, the bus owner requirements and the specifications of the lift. The EL-LIFT specifications are shown in Table 2.

1. Conform to or exceed all pertinent aspects of the CSA Standard.
2. Platform dimensions: 813 mm wide by 1372 mm long (min.).
3. Capacity: 365 kg.
4. Weight: to be optimized.
5. Lift and descent rate: 0.15 m/sec.
6. Length of travel: 1525 mm.
7. Vertical deflection of platform at rated load to be less than 5 mm/1000 mm of platform length.
8. Ramp angle: 1:8 to 1:12.
9. Operating temperature: $-40^{o}C$ to $+60^{o}C$.
10. Automatic sequencing and stops.
11. Bus driver operated.
12. Inside and outside controls.
13. Platform elevated within periphery of bus.
14. Appears as integral component of bus.
15. Will not jack bus.
16. No platform drift at bus floor position.
17. Non-slip platform surface even if wet.
18. Acid-resistant platform surface.
19. User exit/alarm button.
20. Mirrors for driver observation of user.
21. Pivoting jump seat for semi-ambulatory or blind (potential future development).

Table 2 Technical Specifications

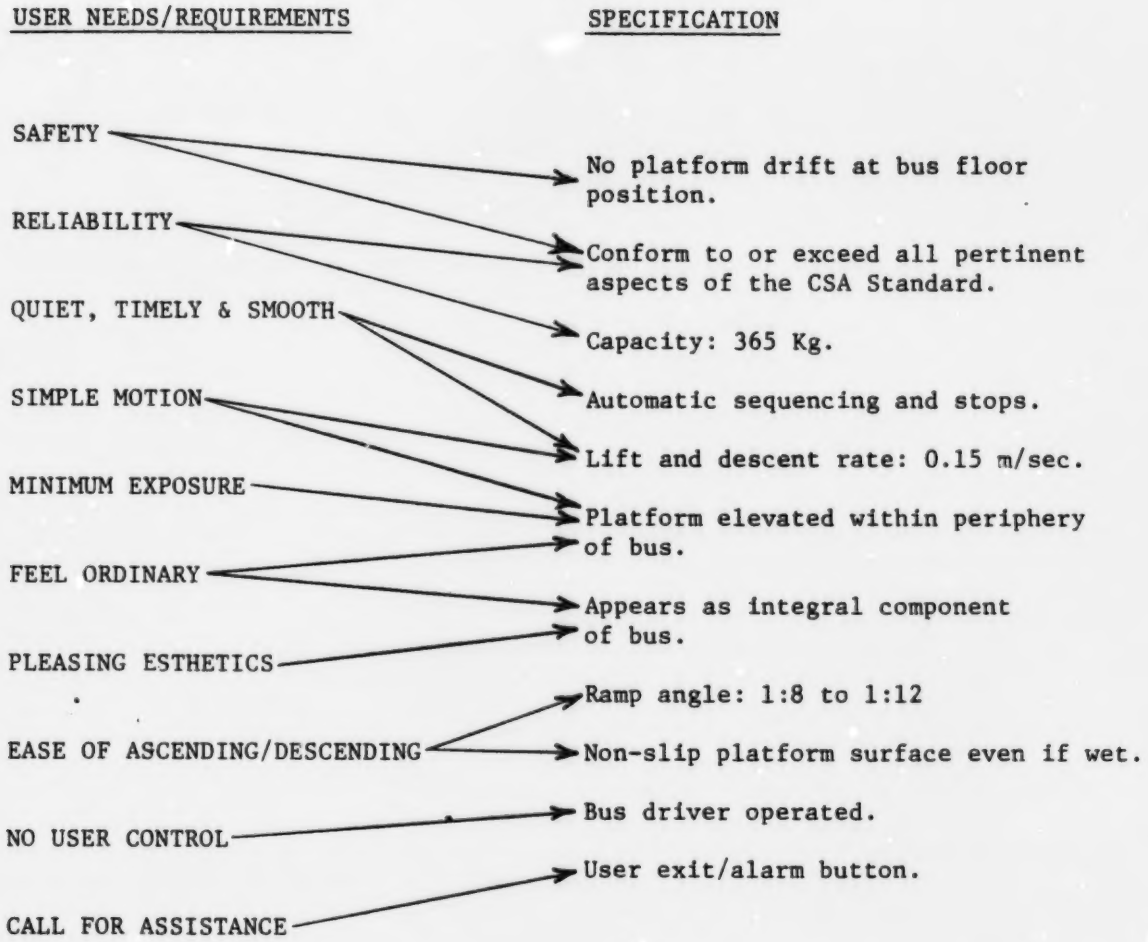


Figure 1 User Needs/Requirements and Specification Relationship

The safety features of the EL-LIFT are shown in Table 3.

1. Manual operation in case of system failure.
2. Interlocked controls to prevent operator error.
3. Interlocked coach systems to prevent coach movement while lift in use.
4. Platform can be stopped in any position.
5. Interlocked with lift exit doors.
6. Restraint system.
7. Automatic upward and downward travel limit stops.
8. Stops during operating cycle if operator control released.
9. Safety barriers around platform.
10. Elevator shaft totally enclosed, well lit and esthetically compatible with the rest of the coach.
11. All pinch points firmly shielded.
12. Safety barrier above coach floor level around elevator shaft manually put in place by the driver and interlocked with lift operation.
13. Audible and visual alarm outside coach while platform or ramp being deployed.
14. Warning marks on portion of lift exposed past periphery of bus and on the lift doors.

Table 3 Safety Features

The bus interface specifications with the EL-LIFT are shown in Table 4.

1. Minimize bus seat loss.
2. Minimize bus baggage compartment loss.
3. Retain structural integrity.
4. Retain systems integrity (e.g. heating ducts).
5. Outside sign on the bus indicating lift location.

Table 4 Bus Interface Specifications

The only known standards on wheelchair lifts are the CSA Standard CAN3-B355-M81 and Veterans Administration Standard VAPC-A-7708-3.

The platform dimensions were limited by the constraints of the bus structure and centre duct. Slightly greater platform dimensions may be attainable when the detail design is done.

The lift capacity was determined as follows in Table 5: (4) (page 111, volume 1).

Maximum power wheelchair weight	135 kg.
Maximum wheelchair user weight	115 kg.
Maximum driver weight	115 kg.
	365 kg.

Table 5 Lift Capacity

The lift controls are automatic and the details of operation are described in Appendix A.

The open space below the lift platform can be used as a luggage compartment when there is no wheelchair user on board. In order to achieve this additional feature, additional design and parts would be required to lock the bottom baggage compartment door. Thus the vehicle owner would lose virtually no luggage compartment space.

5. PRELIMINARY DESIGN

The preliminary design of the EL-LIFT and the integration of this lift into the MC-9 motor coach, was approached with the following design philosophy:

1. Provide the best practical service for the wheelchair user.

2. Economical.

3. Maximum regard for safety.

4. Minimize the loss of revenue to the bus owner.

5. Minimize inconvenience to the driver.

Design compromises were based on the following order of priorities, (listed in decreasing priority order):

a) Safety.

b) Human factors.

c) Simplicity.

d) Reliability.

e) Cost.

f) Ease of use.

g) Serviceability.

In order to maximize product effectiveness and safety, the following criteria were used:

i) Take into account use environments thus anticipating uses and abuses of the product.

ii) Ensure that all modes of operation are considered in the user environment.

iii) Take into account the safety hazards that the user is exposed to during different modes of operation.

iv) Perform failure analysis.

v) Design shall be in accordance to applicable standards and regulations.

vi) The safety aspects of other such product failures shall be considered.

The preliminary design of the lift was achieved by considering all major design and interface aspects. Firstly, the basic lift configuration and operating sequence were determined. Secondly, a mock-up of the lift cavity was built and evaluated. Wheelchair users assisted in the evaluation. Thirdly, wire rope, hydraulic cylinder and screw type systems were analyzed for the actuation system. The screw type of actuation system was selected and was utilized in developing a preliminary design of the lift. Vehicle structural analysis were also done to check vehicle integrity with the lift installed. For further details on the preliminary design, see Appendix A.

6. LIFT DEVELOPMENT PHASE

It is proposed that the lift design of section 1.7, of Appendix A, be developed and incorporated in a bus in order to prove out the design and application. In planning this implementation phase, the factors of risk, cost, schedule and team must be considered.

6.1 Risk

During this preliminary design, it was felt that all major factors of the design were considered. Although some of these factors were not completely investigated and as a result contain some risk in their development. They are as follows:

1. Platform locking system at floor level.
2. Firm telescoping slides to cover the channels and ball screws above the platform to prevent pinch points and to protect these items from dust.
3. A soft start system may be required to obtain a smooth starting movement of the platform.
4. Increasing the height clearance at the lift entrance.
5. Safety nut detection system in case the ball nut fails.
6. Adequate restoration of the heat duct system on the right hand side.

6.2 Cost and Schedule

The schedule for the development of the lift was submitted in the form of a PERT chart and is summarized as follows: (In chronological order and time duration for each group.)

Document structural data; initialize design; detail lift specification and seat layouts.	2 weeks
Structural stress analysis and redesign; actuation system design; preliminary platform, baggage door & lock design; electrical design of actuation system; preliminary electric control system design; partial door & restraint research and specification; & ending with a design review meeting.	4 weeks

Complete electric control system design; bus electrical interface design; detail platform, baggage door & lock design; jump seat and stanchion design; build and install prototype lift into bus frame; test lift; build prototype jump seat & stanchion; generate manuals & drawings; design installation tooling; complete door & restraint research & specification; partial door & restraint design; & ending with a design review meeting.	5.4 weeks
Build bus & final lift; build final jump seat & stanchion; build lift installation tooling; design & build bus interior & lift trim; complete design & build doors & restraint; review manuals & drawings; & endurance test of the prototype lift during the balance of the program.	5 weeks
Instal final lift, doors, baggage door, restraint, jump seat and stanchion; test & modify lift system; & lift Engineering analysis.	3.6 weeks
Instrumented road test, modification & retest; & begin final report.	3 weeks
Instal trim; A/C - heat test; drawings & manuals revisions; & complete report.	2 weeks
Ship to Newfoundland & report printing.	1.4 weeks
Total =	26.4 weeks

The cost for this development would be as follows:

Engineer @ $40/hr @ 7.5 hrs/day =	40 x 7.5 x 370 =	$111,000.00
Manager @ $40/hr @ 7.5 hrs/day =	40 x 7.5 x 25 =	7,500.00
Technician @ $25/hr @ 7.5 hrs/day =	25 x 7.5 x 31 =	5,812.50
Shop worker @ $33/hr @ 8 hrs/day =	33 x 8 x 438 =	115,632.00
Draftsperson @ $25/hr @ 7.5 hrs/day =	25 x 7.5 x 75 =	14,062.50
Designer @ $350/diem =	350 x 121 =	42,350.00
Tech. writer @ $30/hr @ 7.5 hrs/day =	30 x 7.5 x 11 =	2,475.00
Typist @ $12/hr @ 7.5 hrs/day =	12 x 7.5 x 17 =	1,530.00
Material and parts		22,000.00
Stress analysis and tests =		27,599.00
	Total =	$349,961.00

Note: The last number of the multiplication group is man days.

6.3 Team

The project team required to develop and manufacture the lift would consist of two Mechanical Engineers, an Electrical Engineer, an Electrical Draftsperson, a Machine Draftsperson and a skilled group of manufacturing personnel. All the above personnel would have to have experience in the automotive industry.

7. CONCLUSIONS & RECOMMENDATIONS

The engineering analysis performed during the preliminary design indicates that the EL-LIFT project is feasible but with some potential limitations. These are:

1. Lift entrance clearance height from the ground may be a maximum of 1520 mm because of the structural limitations. This may improve but would have to be further analyzed.

2. As a result of (1) above, loading of wheelchair users could be easily done from ground level but caution must be used when loading from curbs to ensure adequate height clearance.

3. It may be feasible to transport freight or baggage in the wheelchair cavity if the lift is not in use.

4. Great care must be taken in the design and development of the platform lock system to be fail safe, because of the safety hazard.

5. Major cut outs would have to be made in the heat duct and parcel racks in the lift area.

6. No attempt has been made to level the platform in the case of uneven terrain.

7. The ramp and lift doors are manually operated by the driver.

8. Caution should be exercised when relying on computer structural analysis to determine structural integrity. True-life conditions are difficult to simulate precisely, thus failure modes may remain undetected which long term field trials might expose.

9. During the January 31/84 meeting between Lugano, Transitec and TDC it was decided that the actuation system would be the ball screw type.

REFERENCES

1. Design Concept for Access of Special Need Travellers to an Articulated Bus, Uwe Rutenberg & Michael Barber, February/83. Transport Canada Report # TP4403E

2. Wheelchair Access Systea for Intercity buses TES Ltd., Sept/81, Transport Canada Report #TP3186

3. Safety Code for Elevating Devices for the Handicapped, Canadian Standards Association, CAN 3-B355-M81

4. Passive Wheelchair Lifts on fixed route Transit Buses, Volume 1 & 2, Dec/81, UMPTA # CA-06-0103

5. Compendium of Transportation Equipment for Disabled Persons, B. A. Smith & R. S. Nishizaki, Transportation Development Centre, TP 3618E

6. VA Standard Design & Test Criteria for Safety & Quality Automatic Wheelchair Lift Systems for Passenger Motor Vehicles, June/77 VAPC-A-7708-3

APPENDIX-A PRELIMINARY DESIGN OF EL-LIFT

1. PRELIMINARY DESIGN

1.1 Basic Lift Configuration

The concept of the EL-LIFT was developed by Les Designers Douglas Ball Inc. (1). The concept consists of an elevator platform that functions within the periphery of the bus. This concept has been retained except the suggested platform slide has been deleted to attain simplicity and improve human factors aspects; namely sliding sideways makes users feel uncomfortable. In order to provide lift access to a maximum variety of wheelchairs, the platform size was maximized. The maximized platform also compensates for the loss of the platform sliding feature by providing more room to maneuver into the elevator cavity. The disadvantage is that more loading area perpendicular to the length of the bus is required. The area required would be the ramp length plus wheelchair length since the user must now back in the wheelchair.

The elevator shaft walls, doors and mechanism covers would be esthetically pleasing and compatible with the bus design. Thus the lift would appear as an integral part of the bus and not an add on item.

A bottom baggage compartment door would be provided to seal the elevator cavity from the outside environment and thus maintain maximum cleanliness. This door would be gasketed at the interfaces to the bus and lift doors. The door would be held in place by four compression springs so that the platform can push it downwards as required during lift operation.

The Douglas Ball Inc. or equivalent wheelchair restraint system would be installed just rearward of the platform. Thus the user is on the platform during the journey.

A "STOP" and "CALL RESET" pushbutton switch would be located next to the window beside the platform. The "STOP" pushbutton switch would be used by the wheelchair user to call for help which would latch on a flashing "Wheelchair User Call" lite on the instrument panel in front of the driver. In order to de-energize this lite, the driver would have to come to the wheelchair user's window area and press the "CALL RESET" pushbutton. This ensures that the wheelchair user's call for help is not forgotten.

The lift control box would be located in a locked compartment which the driver would have to open with a key. The box would be located on the bus wall over the platform. Then the driver would remove the control box to operate the lift. The control box would be connected to the circuitry with a retractile electrical cable so that the driver could travel on the platform with the control box in his/her hand. The control box is stored in the locked box to prevent vandalism.

1.1.1 Operating Sequence

The sequence of operation of the lift would be as follows:

1. The driver stops the bus, puts the gear shifter into neutral and emergency brake on which would complete a portion of the "arm" circuit of the lift. Also the fast idle must be turned on.

2. The driver walks to the lift and stands on the platform.

3. The driver puts the barricade in place which completes another portion of the "arm" circuit of the lift. The barricade prevents anyone falling into the lift cavity when the platform is lowered.

4. The driver unlocks the box containing the control box, opens and removes it. The driver turns the "LIFT ON/OFF" switch to "ON". This arms the lift and applies the brake and accelerator interlocks. Also a "LIFT ON" and "PLATFORM LOCKED" lites are energized on the lift control box and on the driver's instrument panel.

5. The driver pushes and holds the "DOWN" pushbutton and the platform begins to lower. Whenever the lift is travelling downward, two red warning lites would continuously flash. These lites would be located on the outside of the vehicle on either side of the doors. Also an outside chime would be repeatedly sounded at the same time. Also the "PLATFORM LOCKED" lite extinguishes. If the driver releases the pushbutton the platform movement stops. To continue downwards, the driver must again press and hold the "DOWN" pushbutton. See Figure 1.

6. When the platform makes contact with the bottom baggage compartment door, the platform automatically stops then the warning lites and chime are de-energized.

7. In order to continue the downward movement, the driver must open the lift doors and lock them in the 90° position (with respect to the longitudinal axis of the bus). Since the doors don't have windows, the driver must open the doors cautiously to ensure no one is hit by them. After the doors are opened, the driver must check that the area for complete lift lowering is clear. Once the doors are locked in the 90° position, a circuit is completed to allow the complete lowering of the platform. As the platform moves to the ground surface, it also depresses the bottom baggage compartment door to the ground.

8. The driver pushes and holds the "DOWN" pushbutton until the platform automatically stops and the ramp is lowered. No damage to the lift will result if the driver pushes the "DOWN" pushbutton after the lift is fully deployed onto the ground surface. The driver lowers the ramp manually.

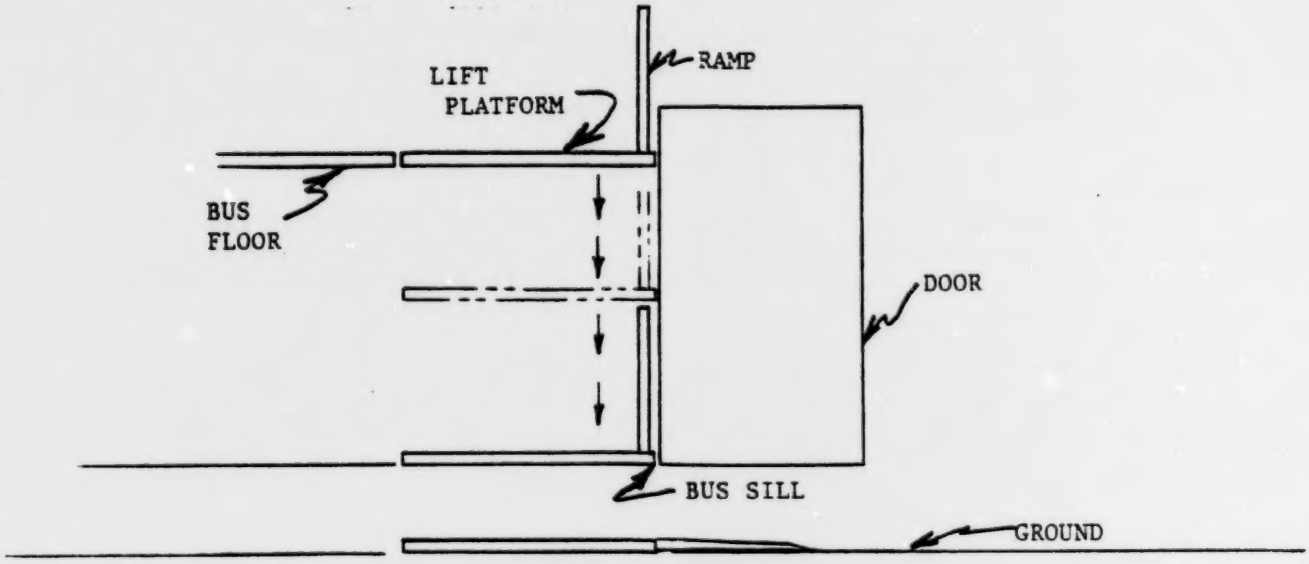


FIGURE 1 LIFT SEQUENCE

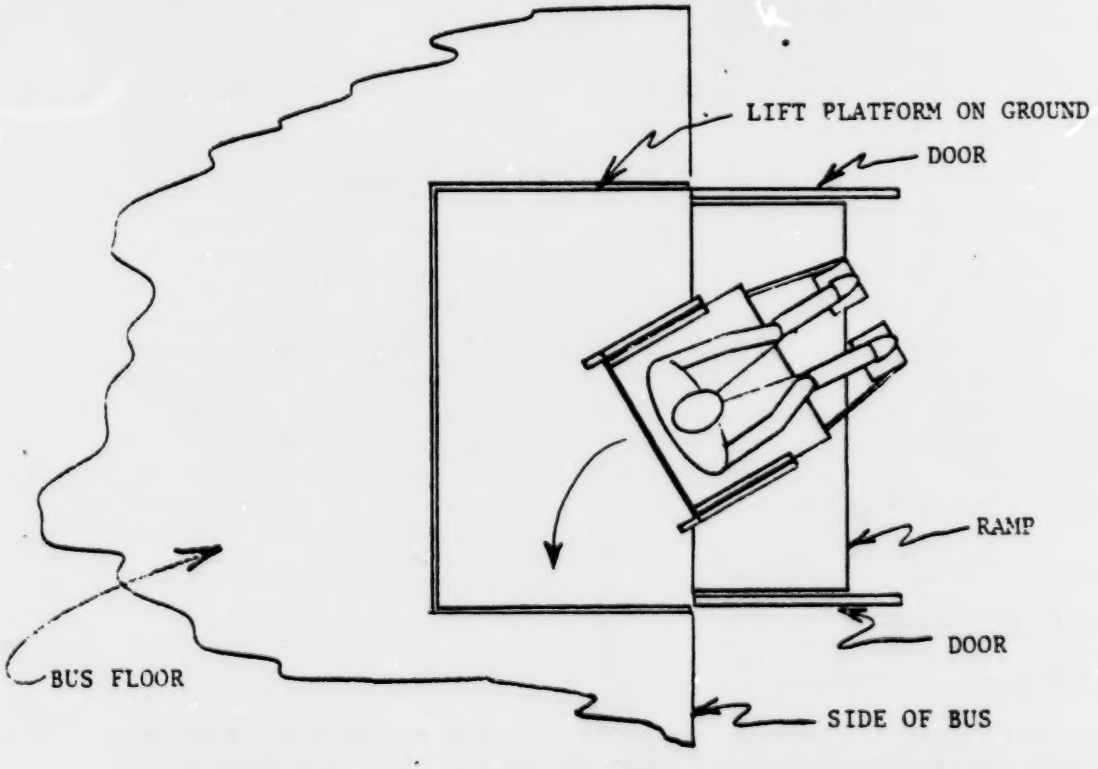


FIGURE 2 MOUNTING THE PLATFORM

9. The driver now exits to the outside to allow the wheelchair user to board.

   CAUTION: The head clearance for a standing person is not adequate so the driver must "duck" his head whenever exiting or entering the platform.

10. The wheelchair user mounts the platform via the ramp in reverse, parks the wheelchair in line with the bus longitudinal axis and applies the brake. See Figure 2. If necessary the driver would assist the user in boarding.

11. The driver enters on to the platform, again "ducking" his head, pushes and holds the "UP" pushbutton. The alarm lites and chime are automatically energized. The ramp retracts to the vertical position, then the platform rises to the level of the baggage compartment door and stops automatically. The alarms are also de-energized automatically.

12. The driver closes the doors, pushes and holds the "UP" pushbutton. No alarms are energized and the platform is elevated.

13. When the platform reaches bus floor height, it automatically stops and four locking pins lock the platform into place. Four mechanical indicators, that are directly coupled to each of the locking pins, show whether the pins have locked the platform securely. This in turn energizes a "PLATFORM LOCKED" lite on the control box via an "AND" circuit consisting of electrical signals from all four locking pins.

14. The driver replaces the control box into the storage compartment and locks the compartment door.

15. The driver assists the user in clamping the wheelchair and strapping the user to the restraint system.

16. The driver turns off the lift power by rotating the "LIFT ON/OFF" switch to the "OFF" position. This in turn de-energizes the brake and accelerator interlocks and "LIFT ON" lite. It will also be considered to include the platform lock circuit as a control of these interlocks. The "PLATFORM LOCKED" lite on the instrument panel remains energized.

17. The driver can now return to performing his other duties.

1.2 Lift Evaluation

1.2.1 Mock-up

A wood and fiberboard mock-up was built to simulate the lift platform, ramp, elevator walls, elevator doors, part of the bus side, and part of the bus window. Figure 3 shows the mock-up. A protrusion was added in one corner to simulate part of a drive and/or track system. The protrusion was located in the area that would affect the entry opening to the wheelchair user.

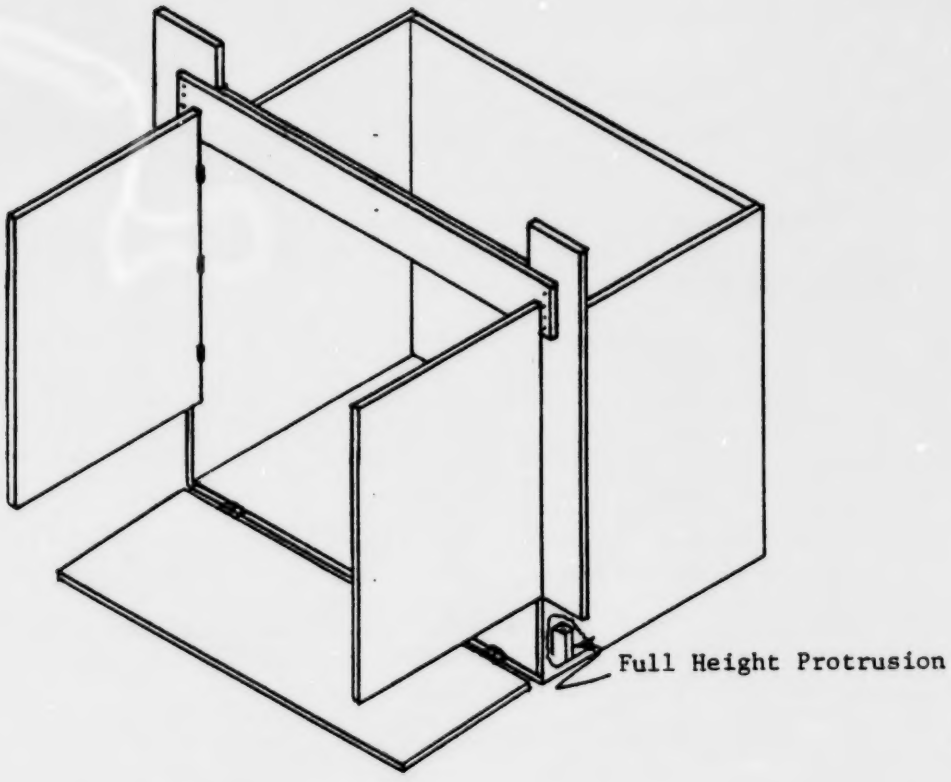


FIGURE 3 LIFT MOCK-UP

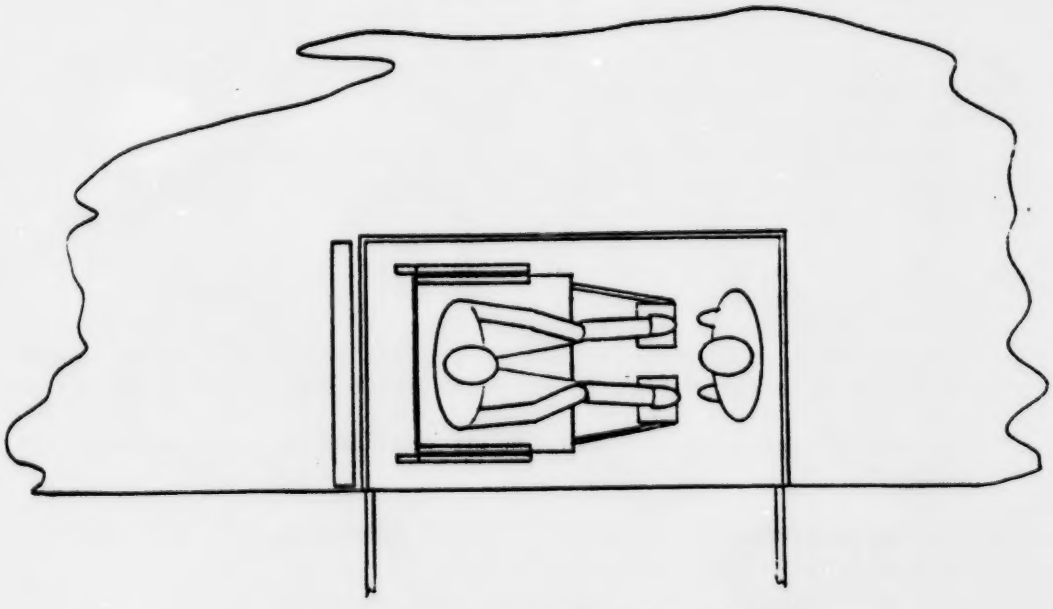


FIGURE 4 USER/STANDEE POSITION

The ramp inclination was 1:10.5 and had a horizontal distance of 605 mm.

The height clearance was made adjustable in order to determine the minimum height level permissable. This would in turn minimize the amount of bus structure removal.

1.2.2 User Review

A panel of eight wheelchair users was organized by Mr. John Lane of the Canadian Paraplegic Association in Winnipeg to review the EL-LIFT design concepts and operational aspects. The mock-up was used to assist in the evaluation.

Discussions took place about the various aspects of the lift and then each panel member entered the mock-up in turn. See Figure 5.

A standee, to represent the driver, entered also with the user still on the platform. The standee then lifted the ramp into the vertical position and closed the doors.

Figure 4 shows the position of the user and standee (driver) on the platform. The standee then explained the sequence of lift operations and the location of the bus areas. The users then presented their evaluations as follows:

1. A sliding platform was rejected especially when loading on an appreciable road crown. The reason was that sliding motion was uncomforting and the panel members preferred to drive into the elevator cavity. Thus they would be subjected to only on simple vertical motion.

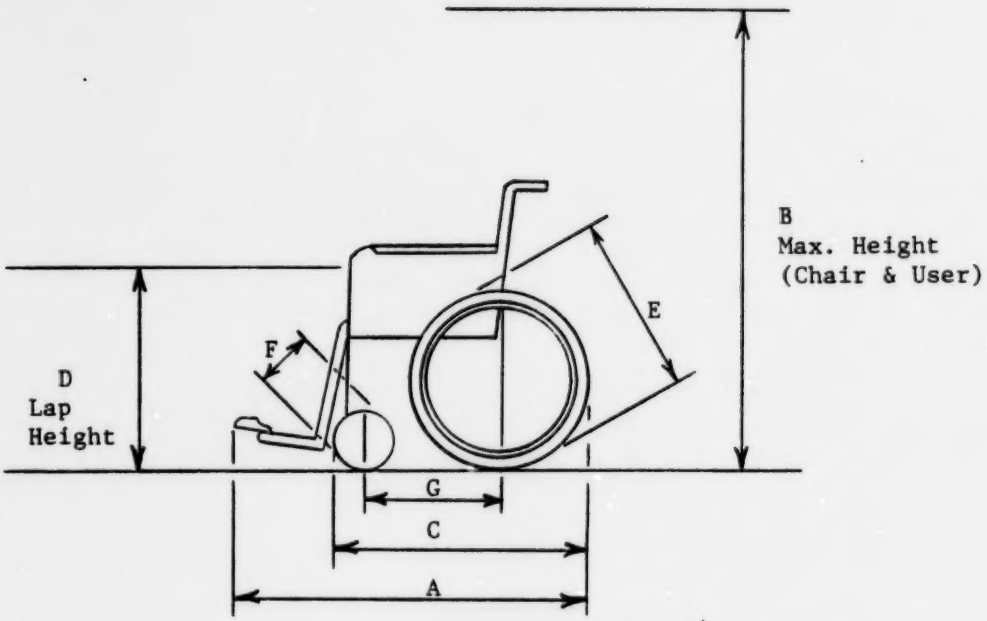
2. All panel members entered the lift elevator cavity very easily in one smooth movement.

3. The panel suggested that the driver accompany the user on the platform in order to mimimize his effort in helping the user aboard. As per operating sequence 1.1.1.

4. Half the panel preferred travelling seated in their wheelchair and the other half preferred to be seated in the regular bus seat. Thus it was suggested that it would be optional to the user to ride in the wheelchair or the bus seat and this in turn could provide capability in carrying additional wheelchair users.

5. The users preferred the containment provided by the elevator walls.

6. The users preferred to have the doors opened to 90^{o} with respect to the longitudinal axis of the bus.



Wheelchair Type	A	B	Width	C	D	E	F	G
E & J Manual	1159	1270	616	902	673	603	203	451
E & J Manual	1175	1270	584	800	641	610	203	438
Swede 24	1118	1270	660	864	648	610	191	406
E & J Power	1178	1321	641	953	667	514	191	552
E & J Power	1210	1346	641	927	686	511	194	533
E & J Power	1321	1283	679	838	673	521	191	546
E & J Manual	1029	1321	622	892	749	610	210	483

FIGURE 5 WHEELCHAIR & USER DIMENSIONS (MM)

7. The users did not object to the doors being closed while being elevated into the bus.

8. In general the users were concerned about inconveniencing the driver and suggested alternatives which would simplify the driver's function.

1.3 Vehicle Structural Analysis

Vehicle structural analysis (Appendix B), by W. E. Wardrop & Associates Ltd., was performed on the basis that the wheelchair lift would be installed in the right hand centre baggage compartment. The goal was to maximize entrance clearance to the lift. The analysis shows that it is uncertain whether the clearance can exceed 1520 mm above ground level. The seat rail support structure, crucial to the structural integrity of the bus, is located at this height. Since this was a preliminary analysis, it is uncertain whether the entrance clearance can exceed 1520 mm until a more detailed computer analysis has been performed. The 1520 mm high entrance would easily permit loading from ground level. For curb loading to occur, as from a 200 mm curb, caution would be required to ensure adequate head clearance. It should be noted that computer structural analyses are not 100% definitive and should be followed by detailed field testing.

1.4 Actuation Methods and Analysis

After various actuation methods were considered only three methods remained that were worthy of detailed analysis.

1.4.1 Wire Rope Actuation

The wire rope actuation method was the simplest method considered. The main disadvantage with it is that it is vulnerable to abuse, poor maintenance and fault conditions that can exist undetected later causing wire rope failure. This presents an extremely serious safety hazard. Thus this actuation method was rejected.

1.4.2 Hydraulic Cylinder Actuation

The hydraulic actuation method has advantages that lend it to this application. If hydraulic cylinders are used as actuators, they provide an inherent safety feature by virtue of their design. Also, simplicity is achieved if the system is powered by the existing bus power steering system. This simplicity would create a high reliability at low cost.

Unfortunately, it appears inadvisable to tap into the hydraulic system of the bus because the following modifications would have to be made:

1. The reservoir would have to be enlarged.

2. The hydraulic system feed would have to be obtained by tapping into the hydraulic lines in the centre duct of the bus.

3. A diverter valve would have to be added.

4. A pressure filter would have to be added.

In addition to the modifications, interaction can occur between the lift hydraulic system and the bus power steering system. An example could be the infiltration of debris from the lift hydraulic system into the bus power steering system due to poor maintenance procedure of the lift. Yet on the other hand this same procedure could be done on the power steering system and in turn contaminate the lift system. Also "break up" from one system can affect the other system.

A logical alternative method of providing hydraulic energy to the lift is to use a separate hydraulic power unit. The unit could be powered by an electric motor. This method adds to the cost and decreases reliability because of the additonal components. Also the system efficiency is severely degraded by the multi energy conversions.

1.4.3 Screw Actuation

The screw actuation method is a good alternative to the hydraulic cylinder system. This method lends itself very well to simple design, and provides high reliability. The major weakness of the screw actuation method when compared to the hydraulic cylinder method is safety. There is a greater chance of a catastrophic failure of the screws, nuts, and/or drive system. A failure would allow the platform to drop suddenly (except in the travel mode because of platform locks). Meanwhile in the hydraulic cylinder method, a failure would most probably allow the platform to drift down slowly. Some of this disparity can be alleviated by aiming towards fail safe design, such as:

1. Conservatively oversizing the screws, nuts, gear box and brake.

2. Utilize two or more independent systems so that if one fails, the other one can still support the platform.

3. Utilize a safety nut system as a back up in case of drive nut failure.

1.4.3.1 Screw Type Selection

Two basic screw types lend themselves to the lift operation, namely the acme and ball bearing screw (commonly called ball screw). Table 1 shows the characteristics of each type.

TYPE	EFFICIENCY	SMOOTHNESS	STARTING TORQUE REQUIRED	WEAR	COST	BACK DRIVE EASE
ACME SCREW	30%	JERKY TO START	HIGH	MUST ADJUST FOR	LOWER	MEDIUM
BALL SCREW	UP TO 90%	SMOOTH	LOW	VERY LITTLE	HIGHER	VERY HIGH

TABLE 1 ACME VERSUS BALL SCREW

The basic cause for the difference between the two screws is that the acme screw relies on sliding motion and the ball screw on rolling motion for actuation. Since the rolling motion has less friction than sliding motion, the ball screw is superior except for the cost. In the lift application the cost difference is insignificant when compared to the other advantages. Thus the ball screw has been selected.

1.5 Actuation Method Selection

It is difficult to decide which should be selected, the hydraulic cylinder or screw actuation method, so much so that we feel that either system could be used successfully. In order to do justice to the selection process, a detail comparison between the two systems has been done. The results are shown in Table 2 and detail analyses are presented in Section 1.5.1 to 1.5.6. A normalized approach is used (i.e. the best system characteristic is given a value of 1 and the same characteristic of the other systems is given a value that is a relative fraction of 1).

1.5.1 Safety

The safety of the hydraulic system is primarily dependent on the hydraulic cylinder and hydraulic backup systems such as check valves, because the hydraulic cylinder directly supports the platform. (In this analysis a catastrophic failure is defined as a failure that would cause the platform to fall). For the hydraulic cylinder to cause a catastrophic failure, hydraulic fluid must be rapidly exhausted from the load carrying side of the piston or breakage of the piston rod or mounts would have to occur. Therefore, if proper design with adequate safety factor is done, the probability of a catastrophic failure of the hydraulic system is very low.

The safety of the screw system is primarily dependent on the screw, nut, drive system and brake. Thus the platform can fall due to:

1. Screw breaking.

2. Nut breaking.

3. Drive system failing in an open coupling condition so that the brake cannot stop the ball screw from back driving.

4. Brake failure.

The severity of these failures can be somewhat reduced as described in Section 1.4.3 Nevertheless, even with conservative design, it appears that the probability of failure of the screw system as compared to the hydraulic system is higher, especially when one considers the greater number of components required to make the ball screw safe.

SYSTEM	SAFETY	RELIABILITY	HUMAN FACTORS	* COST	EASE OF USE	SERVICE-ABILITY	TOTAL
HYDRAULIC CYLINDER (Sharing Bus Hydraulic Energy)	1.0	.987	1.0	1.0	1.0	.8	5.8
HYDRAULIC CYLINDER (Independent Power Unit)	1.0	.974	1.0	.6	1.0	.7	5.3
SCREW	.9	1.0	.9	.6	1.0	1.0	5.4

TABLE 2 HYDRAULIC CYLINDER VERSUS SCREW ACTUATION
(NORMALIZED VALUES)

* The costs are interchanged to conform to the other columns that indicate a favorable result when the number is high.

1.5.2 Reliability

The total reliability of a system is the product of the individual reliabilities of each component in the whole actuator system. It is beyond the scope of this study to determine the precise reliability by such a calculation. Instead an approximate reliability has been determined by judgement and by the number of major components in the system.

1.5.2.1 Hydraulic With Bus Power Reliability

The bus hydraulic system is not included in the reliability estimate of the hydraulic actuator system that uses bus hydraulic power. The following are the major components and their estimated reliabilities:

2 Hydraulic Cylinders	.990
Dual Flow Control Valve	.993
Pilot operated Check Valve	.995
Double Solenoid Control Valve	.990
Pressure Filter	.998
Diverter Valve	.993

Therefore total estimated reliability = .990 x .993 x .995 x .990 x .998 x .993 = .959

1.5.2.2 Hydraulic With Separate Power Unit Reliability

The following are the major components and their estimated reliabilities for a totally independent hydraulic actuator system:

Same as 1.5.2.1 less pressure filter .959 ÷ .998 =	.961
Hydraulic Power Unit	.985

Therefore total estimated reliability = .961 x .985 = .947

1.5.2.3 Screw Reliability

The following are the major components and their estimated reliability for the screw actuator system:

Brake	.990
Electric Motor	.990
3 Gear Boxes	.997
2 Ball Screws	.995

Therefore total estimated reliability = .990 x .990 x .997 x .995 = .972

1.5.2.4 Normalized Reliability

The estimated reliabilities of each actuator system are as follows:

Hydraulic with Bus Power (1.5.2.1) =	.959
Hydraulic with separate power unit (1.5.2.2) =	.947
Screw (1.5.2.3) =	.972

Therefore the reliability of .972 is used as the reference for the normalized value. Then the normalized reliabilities are as follows:

Hydraulic with Bus Power (1.5.2.1) = .959 ÷ .972 =	.987
Hydraulic with separate power (1.5.2.2) = .947 ÷ .972 =	.974
Screw (1.5.2.3) = .972 ÷ .972 =	1.0

1.5.3 Human Factors

The detrimental human factors aspects of the hydraulic systems are the same unless the hydraulic power unit is located in the passenger compartment. The power unit would generate noise and force maintenance inside the passenger compartment. The main detrimental human factor aspect as compared to the screw actuation is the protrusion of hydraulic cylinders from the floor level to the top of the window area.

The main detrimental human factors aspects of the screw actuation method, as compared to the hydraulic system are:

1. The electric motor protrudes behind the restraint system at an uncomfortable height.

2. A universal joint crank would have to be used to manually operate the lift.

1.5.4 Actuation System Costs

The comparative costs between the three actuation systems are as follows:

1. Hydraulic cylinder with bus power =	$1,500.00
2. Hydraulic cylinder with separate power unit =	$2,400.00
3. Screw Actuator =	$2,400.00

The costs can be normalized with respect to $2,400.00. Therefore the normalized costs are:

1. Hydraulic cylinder with bus power =	0.6
2. Hydraulic cylinder with separate power unit =	1.0
3. Screw Actuator =	1.0

1.5.5 Ease of Use

The comparison of ease of use of the three actuation methods are the same, therefore the normalized values are all 1.0.

1.5.6 Serviceability

The serviceability of the actuation equipment depends on the complexity, the type of equipment and location.

1.5.6.1 Hydraulic With Bus Power Serviceability

The comparative serviceability aspects of the hydraulic cylinder system using the bus hydraulic power are as follows:

1. Few components.

2. Basic hydraulic equipment would be used, so sophistication level would be low.

3. The location of all major components, except the cylinders, would be located at the top part of the baggage compartment. This minimizes the servicing inside the bus in order to maintain cleanliness, but this location has poor accessibility.

1.5.6.2 Hydraulic With Separate Power Unit Serviceability

The comparative serviceability aspects of the hydraulic cylinder system using a separate hydraulic power unit are as follows:

1. Medium level of components.

2. More sophisticated hydraulic equipment would be used because of the separate power unit.

3. The location aspects would be the same as in 1.5.6.1 (3).

1.5.6.3 Screw Serviceability

The comparative serviceability aspects of the screw system are as follows:

1. Medium level of components.

2. The components are very simple.

3. The location of the components provide good accessibility but encourage inside passenger compartment servicing.

1.6 Final Actuation Selection

From Table 2, it can be seen that the best actuation system would be the hydraulic cylinder system powered by the bus hydraulic system which has a total score of 1.8.

But in Section 1.4.2 it was pointed out that some problems are inherent with this approach. This system still can be selected but would have to meet with the approval of the bus manufacturer and customer. Then a decision could be made as to what aspects would be most important to them.

The hydraulic cylinder powered by an independent power unit and the screw actuation system remain as the alternatives. The total scores, in Table 2 of these systems are 1.3 and 1.4 which are virtually the same score. Therefore either of these systems can be used and the selection can be based on preferential parameters.

It was decided to select the screw actuation method because of additional minor aspects not tabulated in Table 2, such as cleanliness from hydraulic fluids, better temperature performance and a tidily packaged system.

1.7 Screw Actuator Lift Design

The design concept for utilizing the ball screw actuator is shown in Figure 6. In order to attain clarity of the drawing, various components have not been shown but will be discussed in this section. The lift design would incorporate the functional sequence of 1.1, the specifications and safety features Tables 2 and 3 of Section 4. The lift structure and drive system would be designed to handle the load of the occupants regardless of where they are located on the platform. Figures 7, 8 and 9 show additional details of the basic lift configuration that would be incorporated in the lift design as described in Section 1.7.3.

1.7.1 Lift Structure

The design of the lift structure was based on the channel mast guide system of fork lifts. Two channel guides would be used to support the platform. The channels would be mounted to the side wall frame of the bus, one on either side of the platform. See Figure 6. An important feature of the two channel concept eliminates the need for any protrusions above the floor except at the wall area. The platform would be rigidly connected to an extension support between the mast guide ball bearings and platform. See Figure 10. The purpose of the extension is to ensure that the platform can reach ground level without any drive or guide mechanisms protruding below the sill line of the bus. The ball nut of ball screw drive system is also firmly connected to the same platform extension support.

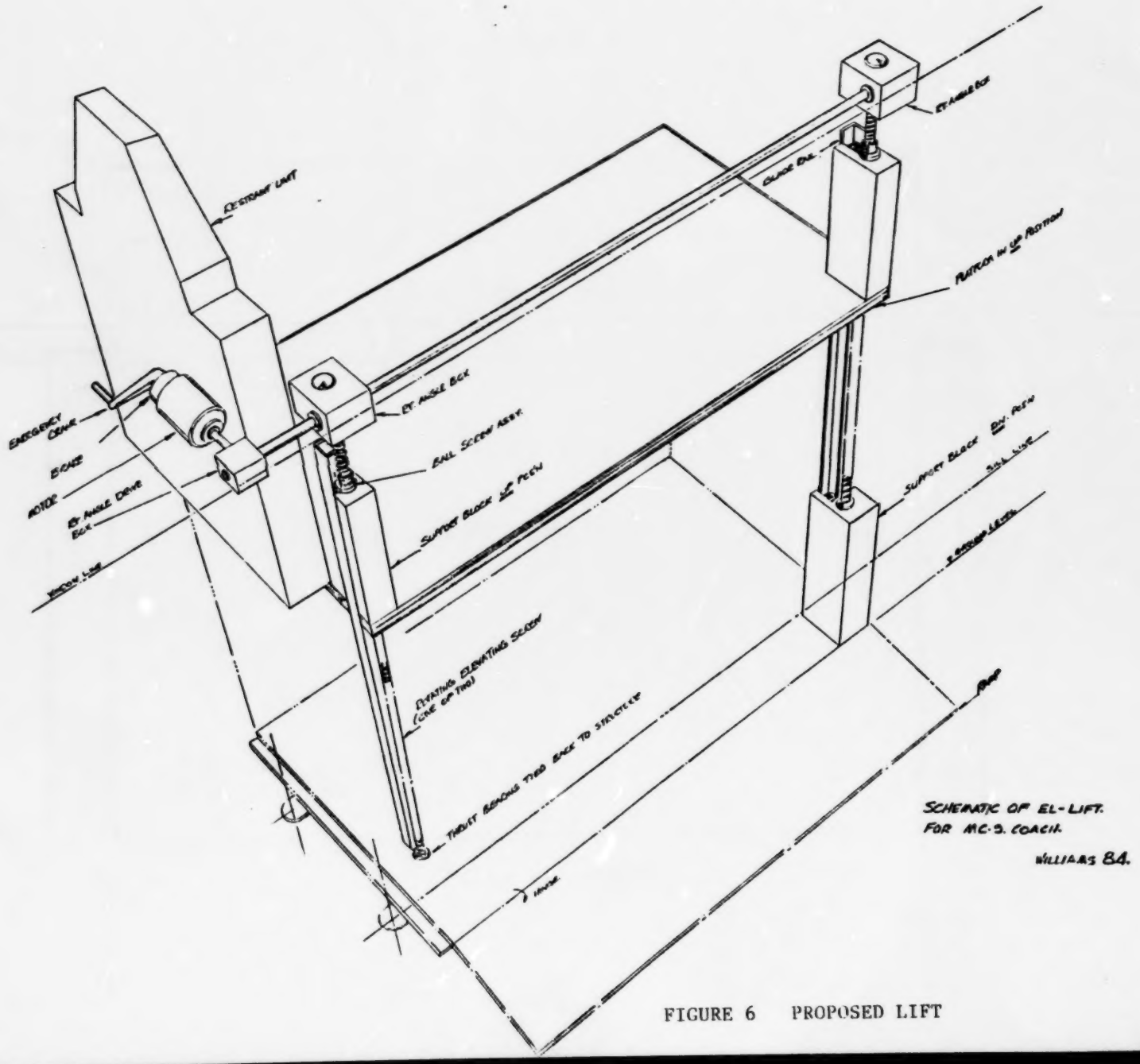


FIGURE 6 PROPOSED LIFT

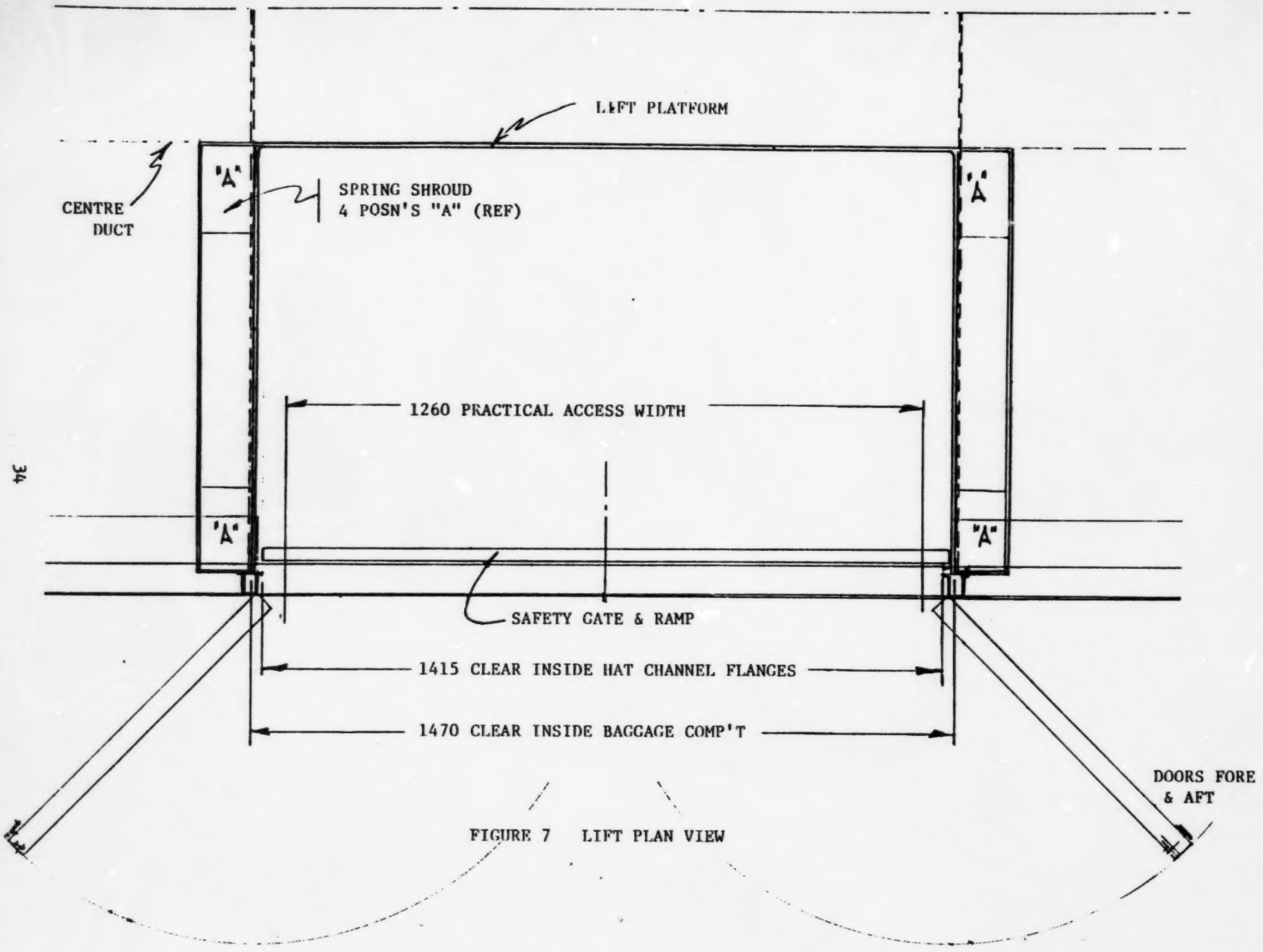


FIGURE 7 LIFT PLAN VIEW

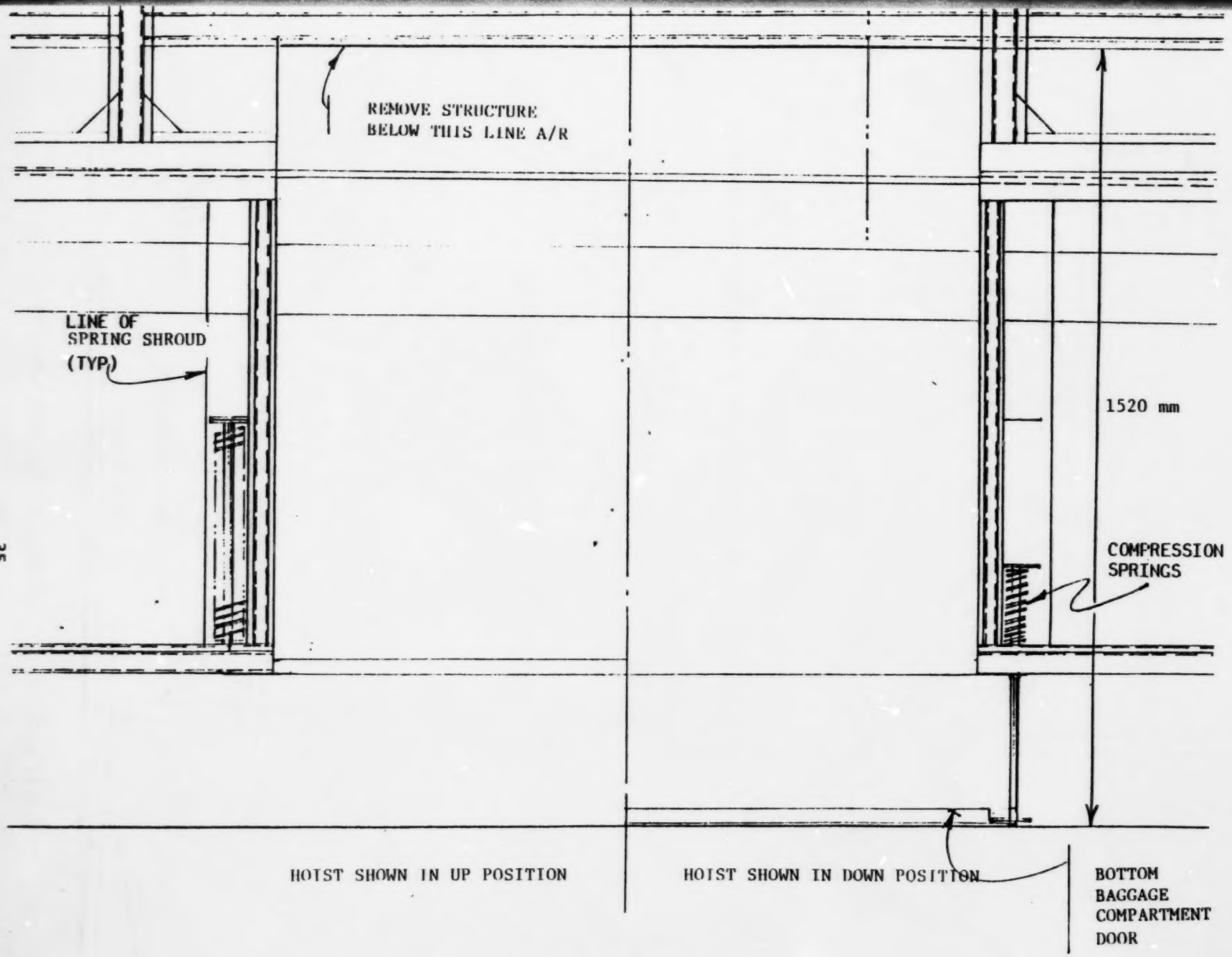


FIGURE 8 LIFT ENTRANCE ELEVATION VIEW

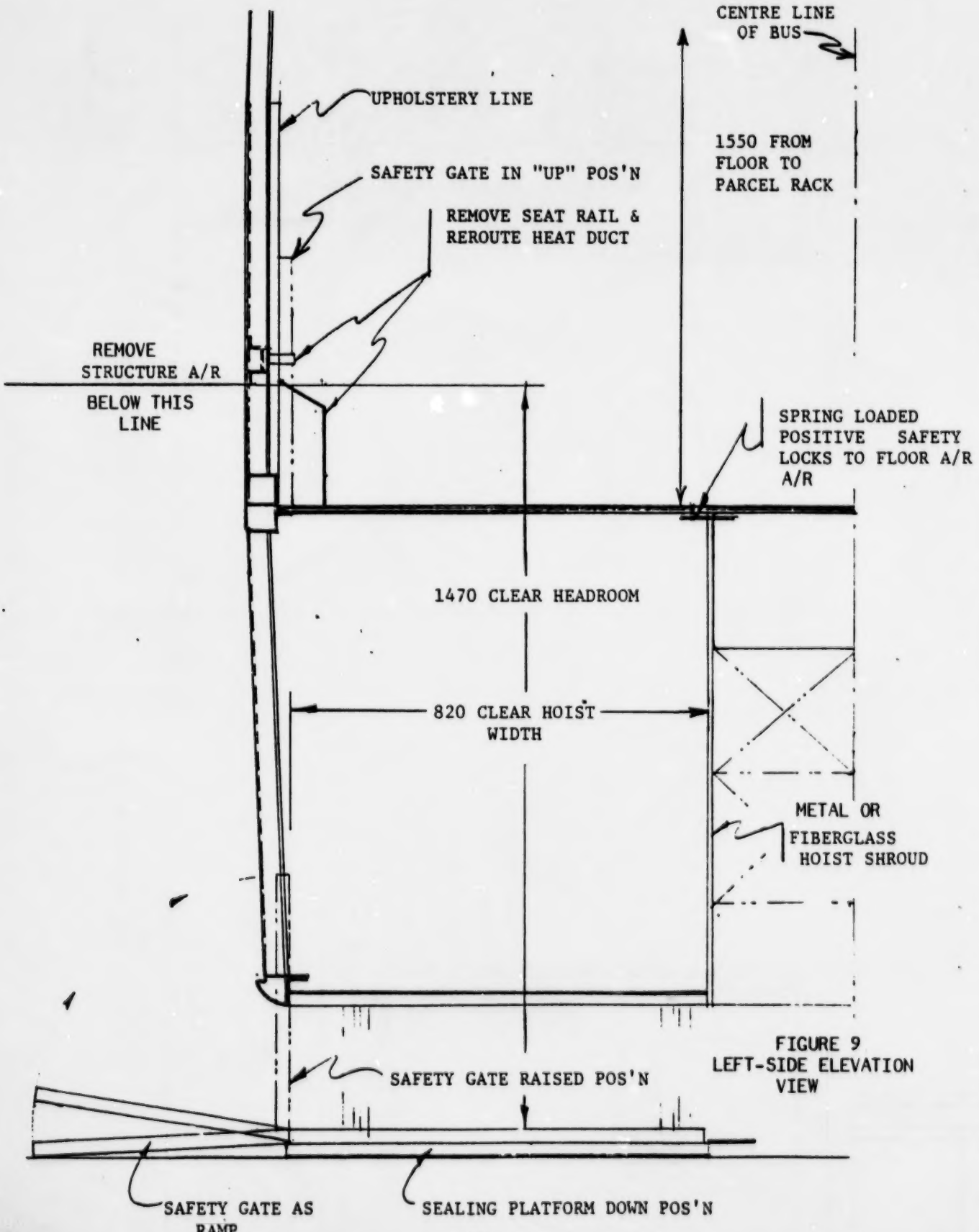


FIGURE 9
LEFT-SIDE ELEVATION
VIEW

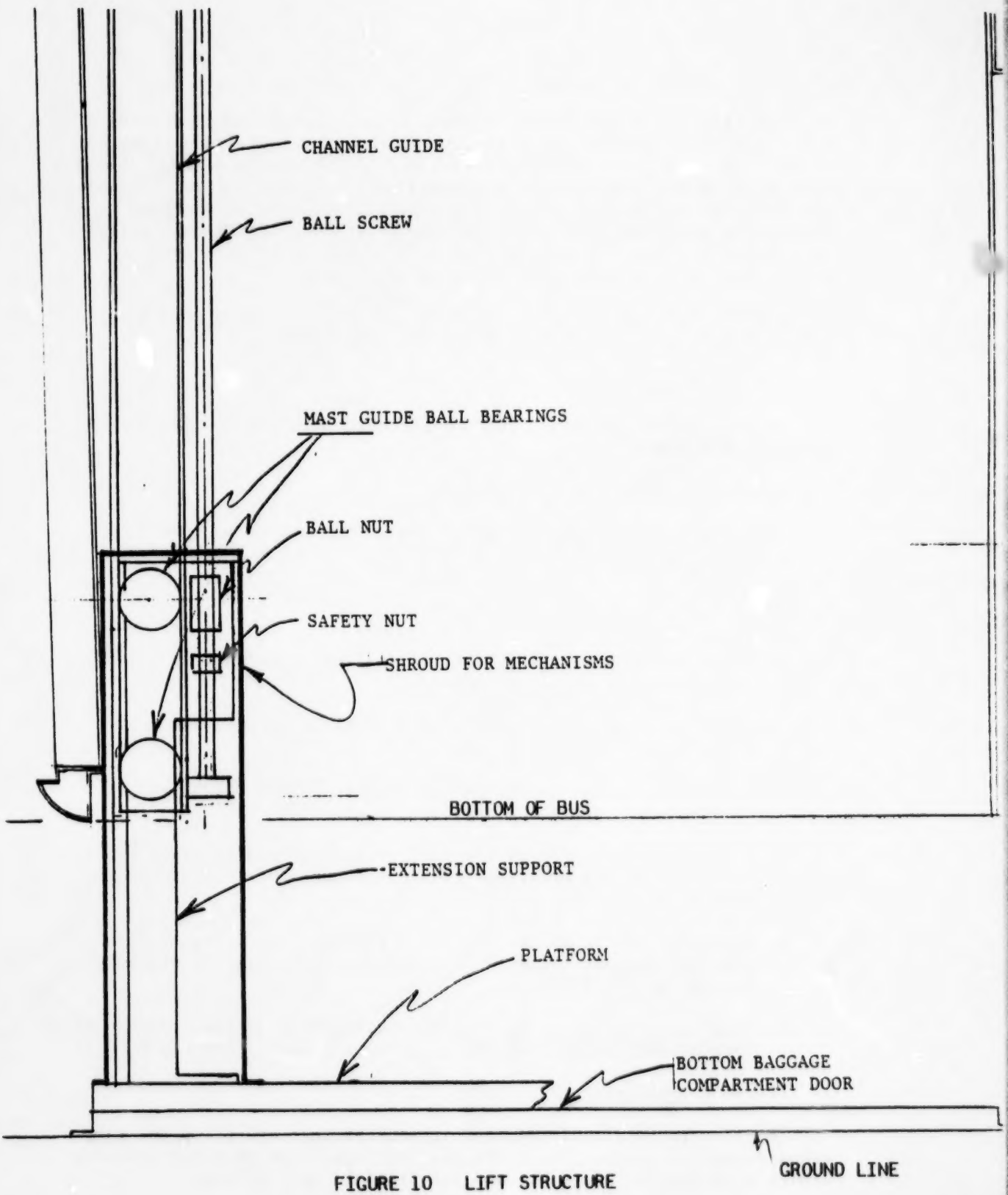


FIGURE 10 LIFT STRUCTURE

1.7.2 Actuation System

The lift actuation system consists of an electric motor driving a 1:1 right angle gear box that in turn drives two single reduction gear boxes. See Figure 6. The gear boxes each drive a ball screw. The ball nuts support the platform, as explained in 1.7.1, which raise and lower the platform as the ball screws are turned. The load on the ball screws are supported by thrust bearings under each of the ball screws near the sill line of the bus. Cut outs in the platform allow the platform to move by the channel and the ball screw.

A hand crank with possibly a universal joint would be used to manually operate the lift in case of equipment failure.

1.7.3 Safety Systems

Various safety features would be included in the lift design. The main features are:

1. Safety nut under each ball nut.
2. Shields and covers to protect users from any moving parts. The covers over the ball screws also protect the ball screws from dust.
3. No pinch points.
4. A barricade between the platform and the aisle must be installed before the lift will operate.
5. Rigid lift walls extend to ground level to protect the user from pinch points.
6. A cut out is made in the parcel rack to permit the driver or standee to accompany the user on the lift.
7. A padding at the top of the lift entrance would be installed in case the standee or driver forgets to duck, because of the low clearance.
8. The doors open and lock at 90^{o} to provide some protection to both the user and passerbys. Also warning decals can be placed on the outside of the doors.
9. When the platform is in the fully elevated position, four positive locking pins would lock the platform in place. See 1.1.1 (13)

1.7.4 Ramp System

In order to retain simplicity, it appears that operating the ramp manually may be best. This would also eliminate the need for trailing cables or pneumatic lines between the platform and the bus.

1.7.5 Materials Selection

The materials selected for the lift would be the same as used to manufacture the bus wherever practical. CORTEN SAE 950 steel is used above the floor and stainless steel 304 2B below the floor in manufacturing the bus.

1.7.6 Weight Analysis

The weight of the lift would be minimized but the required strength would not be sacrificed. The estimated weight of the lift would be 175 Kg.

1.7.7 Lift System Interfaces

The lift would be easily interfaced with the systems of the bus because the only system affected would be electrical. The electrical interfaces would be: (Refer to 1.1.1)

1. Installation of brake and accelerator interlocks.
2. Addition of indicator lites on the instrument panel.
3. Connection of signals from the neutral and emergency brake switches.
4. Twenty-four volt, high current supply from the battery compartment to the lift controls and motor.

APPENDIX B

MCI FEASIBILITY ANALYSIS FOR A WHEEL CHAIR LIFT INSTALLATION

INTRODUCTION

An initial visual inspection of the existing MCI bus frame indicated the best potential location for the wheel chair lift assembly to be at the current location of the central baggage compartment. The installation would involve the removal of several key structural components to create the necessary opening. A simplified ANSYS model was generated to study the effects of the removal of these members and the necessary modifications restore to the frame to its original stiffness.

SCOPE OF ANALYSIS

The analysis is a preliminary investigation to study the feasibilty of the installation of a wheel chair lift assembly. The actual defections obtained are only compared on a relative basis and cannot be applied to the orignal bus frame due to the simplifications in the model. Static loading only was considered; no dynamic effects were studied.

ANALYSIS APPROACH

Several static load conditions were analyzed using the original frame geometry to obtain values of frame stiffness. Appropriate structural modifications were then made to accommodate the wheel chair lift. The same load conditions were then re-analyzed to obtain the new deformations. Comparison of the modified frame deformation results with the original frame results were reviewed to give an indication of the relative frame stiffnesses. Ideally, the modified frame should be as least as stiff as the original frame.

ANSYS MODEL

Two types of elements were used; three dimensional elastic beam elements and quadrilateral shell elements. The ANSYS model shown in Figure 1.0 consisted of the sidewall and baggage compartment floor structure. The side wall sheet panels were not included. The section properties of each of the significant structural members in the sidewall and baggage floor were computed and implemented into the ANSYS model to properly simulate their individual contribution to the stiffness of the overall frame structure.

MATERIAL PROPERTIES

All materials were assumed to have linear and elastic properties. The following properties were used for the stainless steel and steel sections.

Modulus of elasticity = 29;000,000 psi
Poisson ratio = 0.3

To simplify the modelling of the corrugated Aluminum sheet used for the baggage compartment floor, the material properties for the aluminum were altered to reflect the difference in stiffnesses in the plane of the sheet. The following properties were used.

Modulus of elasticity (Z-axis)
paralell to the corrugations = 10,000,000 psi
Modulus of elasticity (X-axis)
perpendicular to the corrugations = 1,000,000 psi
Modulus of elasticity (Y-axis)
perpendicular to the plane of the sheet = 10,000,000 psi
Poison ratio's NUXY = 0.20
NUXZ = 0.20
NUYZ = 0.32

This allowed a reasonable representation of the corrugated sheet with shell elements.

LOADING

Four loading conditions, shown in Figure 2.0, were applied to the original simplified frame and were reported for each modification of the frame.

The first load condition was a 1000 lb axial load applied in the X-direction on the sidewall at the floor level. It was designed to investigate the effects of cutting out a portion of the belt rail on the axial stiffness of the sidewall at the floor level.

The second load condition was a 1000.0 lb axial load applied in the X-direction at bottom outside runner of the baggage compartment. Similarly, this load condition also tested the axial stiffness at the bottom of the frame.

Load condition three was designed to investigate changes in torsional stiffness of the frame. This was achieved by applying a 10.0 lb load perpendicular (the Z-direction) to the side wall near the top-front corner of the frame.

The last load condition was a vertical loading (Y-direction) applied at the two central baggage compartment dividers to investigate the vertical stiffness of the frame. The magnitude of these were 500 lb each.

FRAME MODIFICATIONS

Two frame modifications were investigated:

The first modification involved removing the axial running frame members within the central baggage compartment area up to but not including the seat rail. This gave and effective height clearance of about 60 inches from the ground. Several members in the transverse direction of the bus and the central baggage compartment floor were removed to give the required 36 inch transverse depth.

In an attempt to regain the loss of frame stiffness additional members had to be added. Four diagonal members of the same section properties as the current runners were added at the baggage compartment floor to re-establish the axial load path for the runners that were removed. The seat rail section properties above the wheel chair lift opening were increased to match that of the section removed at the floor level, and additional diagonal members of the same section properties were installed to divert the axial load path into this member. Two other diagonal members of the same section properties of the original seat rail were included in the two panels directly above the first set of additional diagonals. Figure 3.0 shows frame modification 1.

The second modification involved changing the fisrt modified frame to give an increased clearance in the wheel chair lift opening to allow for a 6 inch curb. This required raising the section at the seat rail another 7 inches as shown in figure 4.0. The same section properties as used in the first modification were used for this goemetry.

RESULTS

Tables 1 through 4 summarize the results of the analysis.

TABLE 1 - LOAD CONDITION 1

	Deflection at Load Point (in)	Relative Stiffness
Original frame	0.00568	1.00
Modification 1	0.01066	0.532
Modification 2	0.03404	0.167

TABLE 2 - LOAD CONDITION 2

	Deflection at Load Point (in)	Relative Stiffness
Original frame	0.00576	1.00
Modification 1	0.00892	0.645
Modification 2	0.00898	0.641

TABLE 3 - LOAD CONDITION 3

	Deflection at Load Point (in)	Relative Stiffness
Original frame	0.228	1.00
Modification 1	0.192	1.19
Modification 2	0.197	1.16

TABLE 4 - LOAD CONDITION 4

	Deflection at Load Point (in)	Relative Stiffness
Original frame	0.144	1.00
Modification 1	0.0529	2.72
Modification 2	0.0812	1.77

MODIFICATION 1 - DISCUSSION OF RESULTS

Application of the first two load conditions to this geomtry indicated the axial stiffness of the frame was reduced to between 0.53 and 0.64. This was primarily due to a decreased bending resistance of the sidewall structure. This could be improved marginally by increasing the section modulii of the upper sidewall horizontal running members. A more important factor will be the effect of the skins in resisting increased frame distortion. However buckling and cracking may become a problem if the skins are not sized properly and become over stressed.

Another means of improving the axial stiffness may be to divert the axial load in the sidewall at the floor level through the passenger floor via a similar truss section as that used at the baggage compartment floor. This modification could be evaluated in a more detailed model.

The third and fourth load conditions indicated an increase in the modified frame stiffness in resisting torsional and vertical loading. The 2.7 increase in vertical stiffness can be attributed to the truss effect offered by the additional diagonal members in the sidewall. A 1.2 increase in torsional resistance can also be attributed to the addition of the diagonal members in the sidewall and baggage floor. Frame stiffnes does not appear to be a problem for these load conditions.

A potential dynamic problem may be induced due to the non-symmetrical frame stiffness. This effect was beyond the scope of this study.

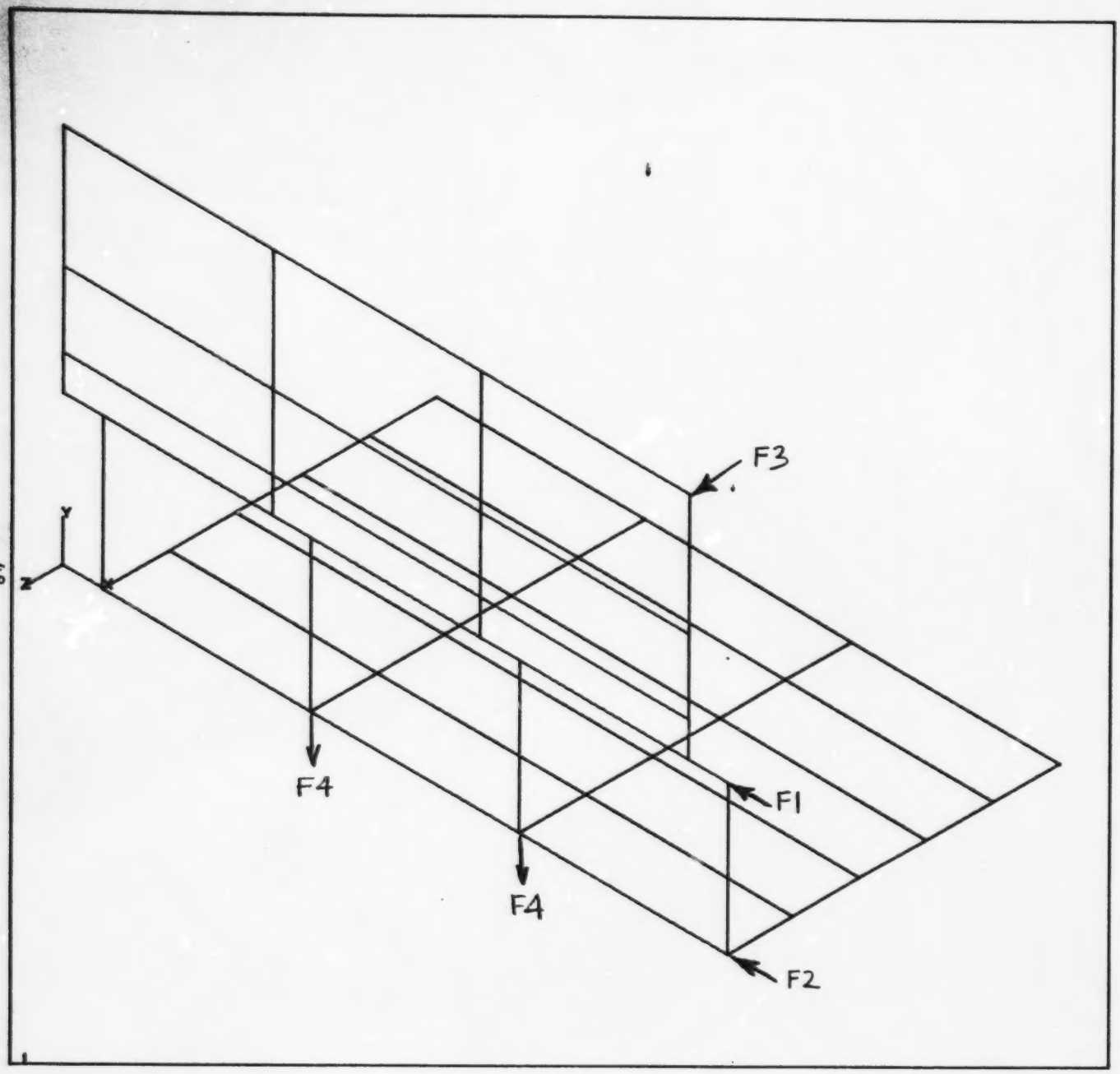
MODIFICATION 2 - DISCUSSION OF RESULTS

The resulting axial frame stiffness was reduced by about one sixth of that of the orignal frame for the load applied axially at the passenger floor level. This was due to less efficient load transfer above the wheel chair lift opening and resulted in the baggage compartment vertical dividers resisting the load in bending. This geometry may work if the axial load path were diverted through the passenger floor using diagonal trussing rather than attempting to resist the load through the sidewall.

The axial stiffness at the bottom of the frame remained about the same as that in the first modification. This indicates the axial load applied to bottom runner is being diverted through the baggage compartment floor diagonal trussing and is not significantly affected by changes in height of the wheel chair lift opening.

Torsional stiffness and vertical stiffness of the frame was increased by 1.16 and 1.7, respectively, due to the addition of the diagonal members. As with modification 1, the last two load conditions appear to be no problem.

No attempt was made to duplicate stiffness of the skins (which will significantly contribute to the stiffness). Much of the bending which occurred in this model would have been removed by the skins. Therefore, building up the sections may be a very inefficient method of restoring stiffness to that of the original bus.



1/ 5/84

13.4786

PLOT NO. 1

PREP7 ELEMENTS

AUTO SCALING

XV=1

YV=1

ZV=1

DIST=102

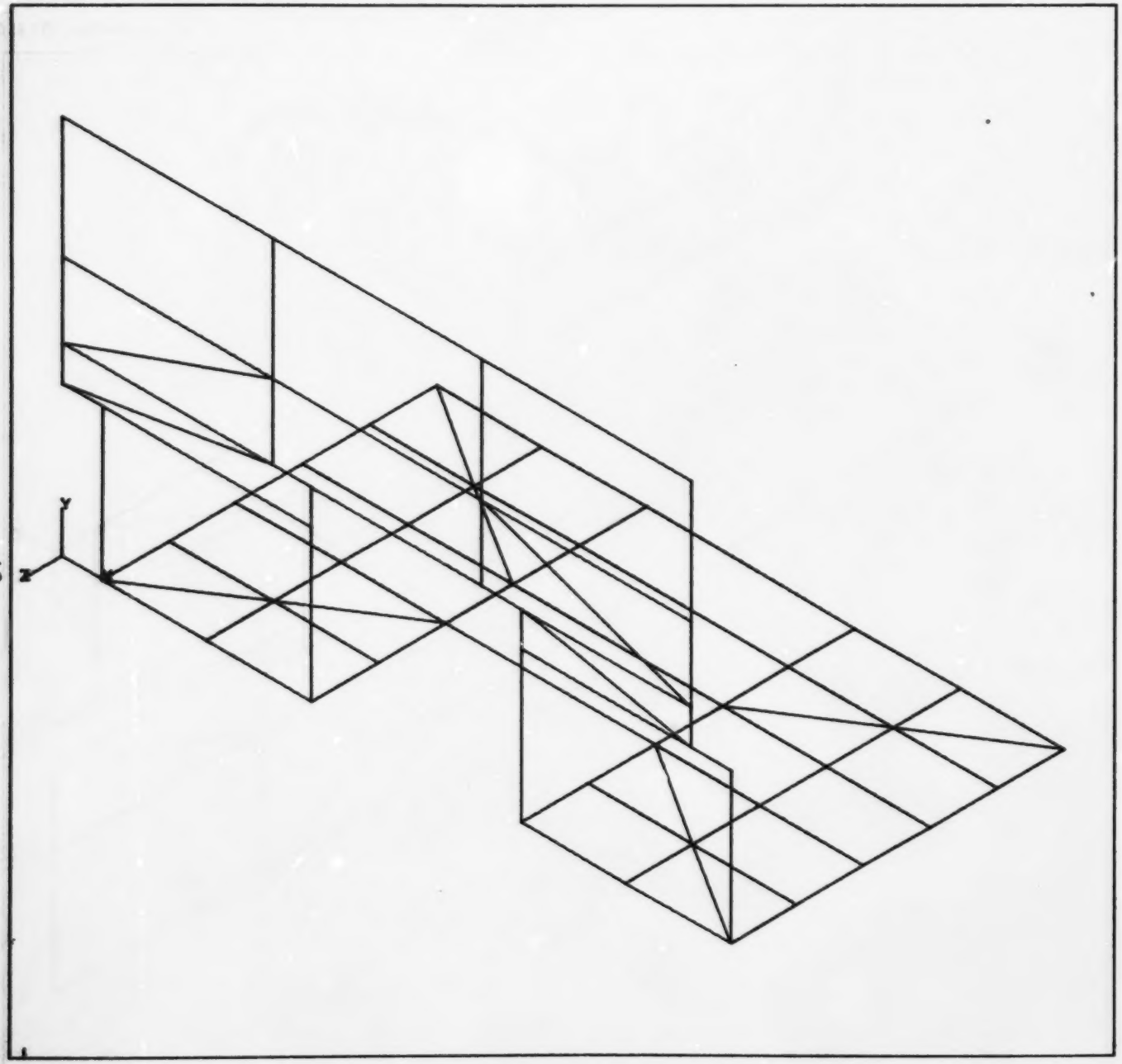
XF=100

YF=37

ZF=-38.5

MCI PRELIMINARY BUS ANALYSIS

FIG. 1.0 & 2.0



1/12/84

14.5934

PLOT NO. 1

PREP7 ELEMENTS

AUTO SCALING

XV=1

YV=1

ZV=1

DIST=182

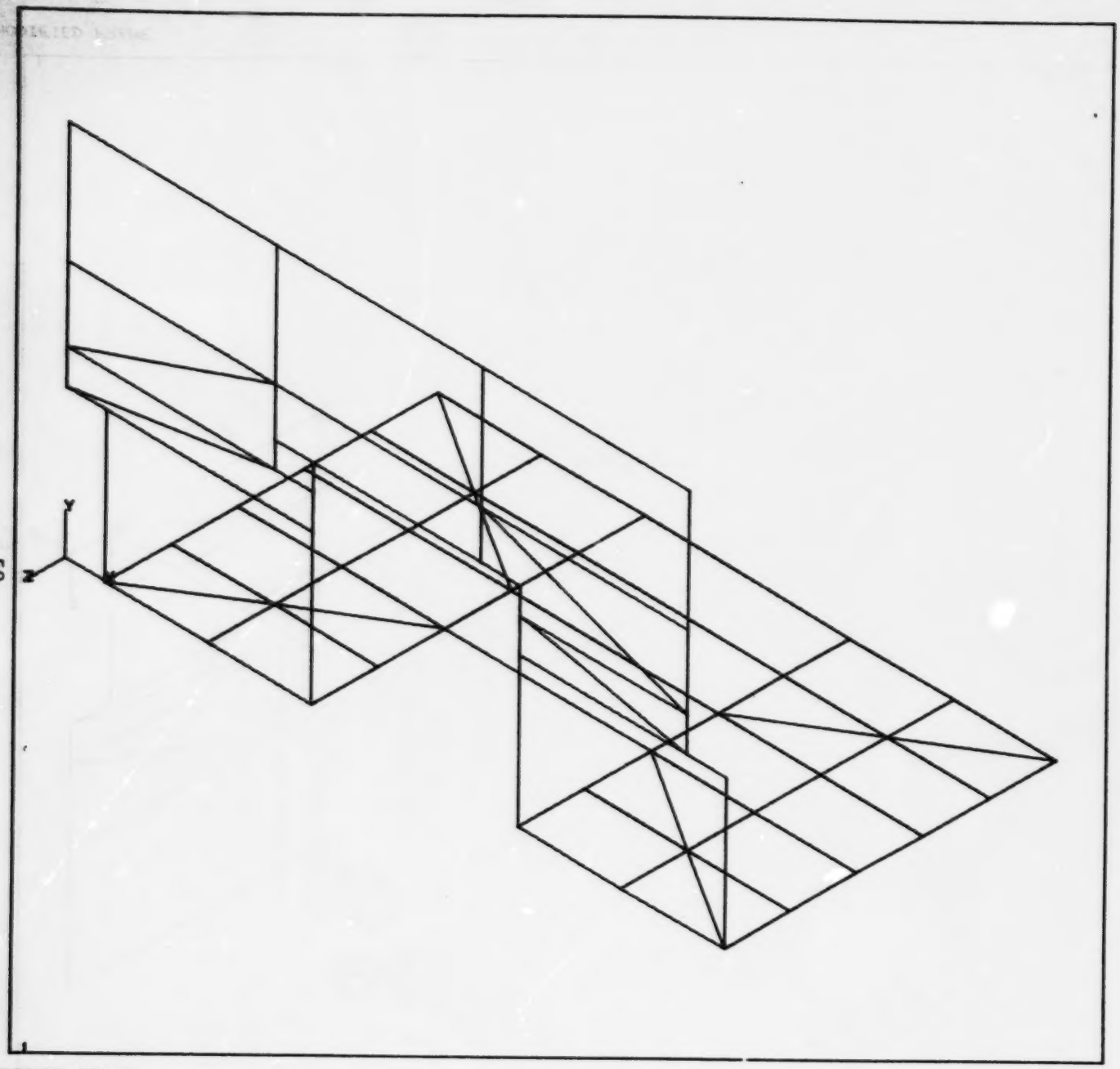
XF=100

YF=37

ZF=-38.5

MODIFIED FRAME

FIG. 3.0



1/16/84

21.7020

PLOT NO. 1

PREP7 ELEMENTS

AUTO SCALING

XV=1

YV=1

ZV=1

DIST=102

XF=100

YF=37

ZF=-36.5

MODIFIED FRAME

FIG. 4.0

CONCLUSIONS

1) Based on the simplified model used in this analysis, the first modified geometry is the more feasible of the two geometries considered.

2) The frame stiffness for the first modified version was sufficient in resisting torsion and vertical loading but the axial stiffness was reduced to between 55 and 65 percent of that of the original frame. This could potentially be improved by diverting this load through the passenger floor.

3) The second frame modification resulted in a one sixth reduction in axial frame stiffness. It appears raising the height of the wheel chair lift opening above the seat rail is not feasible.

4) The concept appears viable in that the loss of stiffness is not an order of magnitude lower than that of the original frame. Additional study uitilizing a full model would likely achieve stiffness approaching that of the original frame.

5) Non-symmetric effects of the cutout may be important in producing dynamic asymmetry.